The use of Soybean Meal and Full Fat Soybean Meal by the Animal Feed Industry

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Introduction

Soybean meal is a major source of protein used by the pig and poultry industries in Australia. Manufacturers of companion animal foods, such as dog foods, also use soybean meal in their diets. As well, this versatile protein is being used as a source of protein in aquaculture diets. Soybean meal is an important source of protein for animals due to its excellent amino acid composition and high level of digestibility.

The first attempts to feed soybeans to animals were unsuccessful with poor growth observed as compared with feeds containing other sources of protein. In 1917, Osborne and Mendel found that good growth could be demonstrated if soybeans were first heat treated before incorporation into the diet for animals. Later it was found that heating resulted in denaturation of protease inhibitors that interfered with digestion.

Because soybean meal is the principal source of protein for the feed industry worldwide, it has become an ingredient that is strategically traded around the globe every day of the year. Feed manufacturers use soybean meal as the standard against which other protein sources are compared. Soybean meal has also become the protein source that determines the price of proteins for livestock feeding.

Throughout the world, the use of vegetable proteins in animal feeds is becoming increasingly important because of consumer concerns about the health and safety of animal protein by-products and a reduction in fish stocks. This will place further demands upon soybean meal as a source of protein for livestock.

Composition

The extent to which soybean meal is used in diets for pigs and poultry is determined to a large extent by its cost effectiveness in supplying essential amino acids, particularly lysine, methionine and threonine. Several commercial software packages are available to carry out the many iterative computations involved in formulating a diet from a list of 30 or more feed ingredients. Because the availability and cost of feed ingredients are extremely dynamic in the market place, diet formulations constantly change in response to prevailing conditions.

Soybean meal is a concentrated source of protein and energy and is lower in crude fibre than most other oilseed meals (Table 1).

Table 1. Comparative value of various oilseed meals [1]

	Crude protein (%)	Digestible energy (MJ/kg) [2]	Crude fibre (%)
Soybean meal	48.0	14.9	6.2
Full fat soybean meal	38.0	19.5	5.5
Canola meal	35.0	12.2	12.1
Cottonseed meal	39.0	13.0	13.1
Sunflower meal	30.0	8.3	25.5
Peanut meal	46.0	14.85	10.3

1 As-fed basis

2 Digestible energy for pigs

Full fat soybean meal also has these features, but in addition, is an even more excellent source of energy and fatty acids. A comparison of solvent extracted soybean meal and full fat soybean meal is shown in Table 2.

Table 2. Comparative amino acid composition of soybean meals

	Soybean meal – solvent 48%CP	Soybean meal - full fat
Dry Matter (%)	90.0	90.0
Crude protein (%)	48.0	38.0
Digestible energy (MJ/kg)	14.9	19.5
Crude fibre (%)	4.2	5.5
Available Lysine (%)	2.63	2.11
Available Threonine (%)	1.58	1.30
Available Methionine (%)	0.60	0.52
Available Isoleucine (%)	0.61	1.58
Available Tryptophan (%)	0.59	0.43
Fat (%)	2.5	19.0
Available phosphorus (%)	0.24	0.19
Calcium (%)	0.30	0.23

Diets formulated for growing pigs to supply a desired lysine/energy ratio must take into account a number of factors that influence utilisation of lysine and other amino acids. These include the form of the lysine in the feed and the balance of other essential amino acids.

The availability of lysine in a feed is defined as the proportion of the total lysine that is in a form suitable for digestion, absorption and utilisation. Availability is affected by the physical form of the diet, processing conditions, the presence of anti-nutritional factors and the form of lysine.

Soybean meal has an excellent profile of essential amino acids and these amino acids are highly digestible. A comparison of the digestibility with other protein sources is presented in Table 3. Soybean meal has the highest lysine digestibility (91%) of any of the commonly available protein sources. It also ranks high in methionine, cystine and threonine digestibility. In addition, the variation in digestibility is less for soybean meal as compared with other oilseed meals.

Table 3. The standardised digestibility values of lysine, methionine, cystine and threonine in various protein sources

	Standardised digestibility (%)			
Protein source	Lysine	Methionine	Cystine	Threonine
Canola meal	75.3	87.1	81.0	74.5
Cottonseed meal	63.3	72.8	75.7	70.7
Peanut meal	83.0	88.0	78.0	
Soybean meal	91.5	92.9	88.6	87.7
Sunflower meal	60.0	91.5	82.1	81.4

Source: AmiPig, Aventis Animal Nutrition

Production

In a typical year, Australia produces about 30,000 tonnes of soybean meal, yet the animal industries require from 184,000 to 356,000 tonnes of soybean meal . Due to the severe domestic production shortfall, Australia is a net importer of soybean meal and imports from 150,000 to 300,000 tonnes/year from the US (Table 3).

In 2002/03, it is likely that Australia will have one of its smallest soybean crops on record, with the dry conditions severely restricting plantings. Thus, high imports will occur in 2002/03 to make up for the shortfall.

Although, the principal soybean product produced in Australia and imported from the US for the animal feed industry is solvent extracted soybean meal, there is also interest in using fullfat soybean meal in animal feeds. Approximately 20,000 tonnes of full fat soybean meal is produced annually in Australia.

Table 3. Oilseed meal usage in Australia (000's tonnes)

	Range (excluding major drought years)		
Meal type	**Typical year**	**Min**	**Max**
Canola	228	210	246
Soybean	32	32	56
Sunflower	48	42	72
Cottonseed	160	144	224
Total	468	428	598
Plus Imports			
Soybean	200	150	300
Other	20	10	25
Total Imports	220	160	325
Total Meal Usage	688	588	923

Source: Australian Oilseeds Federation

Processing

The standard process for solvent extracted soybean meal production involves a series of treatments. These include cracking, dehulling, flaking, extraction, followed by desolventising and toasting.

Fullfat soybean meal is produced by heat treating soybean seeds either by steam, followed potentially by extrusion, toasting, and micronising, or jet sploding to produce a high oil, high protein product.

Antinutritional factors

Natural ant-nutritional factors (ANFs) are found in all oilseed proteins. They are described as non-fibrous naturally occurring substances exerting negative effects on the performance or health of animals (van Barneveld et al., 1997). Soybeans contain protease inhibitors, allergens, lectins, phytoestrogens, lipoxygenase, saponins, oligosaccharides and phytin (Swick 1994).

All legumes, including soybeans, contain protease inhibitors. These are plant proteins that bind and inactivate digestive enzymes within the gastrointestinal tract of the animal. Soybeans contain trypsin inhibitors that inactivate the pancreatic enzymes trypsin and chymotrypsin. This reduces protein digestibility and causes pancreatic swelling as this gland attempts to produce more enzymes to make up for the excreted loss. The lost enzymes, being rich in sulphur amino acids, further reduce the amino acid status of the animal.

Proper heat treatment in combination with the correct moisture level destroys the trypsin inhibitors. For soybean meal this is accomplished in the desolventising/toasting chamber. In the case of full fat soybean meal, the most common method is extrusion.

Insufficient heating, or under-processing, of soybean meal negatively affects amino acid digestibility because the anti-nutritional factors are not adequately destroyed. Excessive heating, or over-processing negatively affects amino acid digestibility because a portion of the amino acids have either been destroyed or tied up as indigestible, bound compounds. Lysine and cystine are particularly vulnerable to over-processing. Additionally, the usable energy content of over-processed soybean meal is substantially reduced.

Work by Anderson-Haferman et al., 1992 shows the effect of inadequate heat processing on the amino acid digestibility of soybean meal (Table 5). These data show that the digestibility of lysine, methionine, cystine and threonine was greatly increased as the result of heat treating soybeans. This was also true for the other essential amino acids.

Table 5. Effect of under-processing soybean meal on amino acid digestibility of raw soybeans (%)

Autoclave time (mins)	Lysine	Methionine	Cystine	Threonine
0	73	65	67	64
9	78	70	70	68
18	87	86	83	82

Anderson-Haferman et al., 1992

Trypsin inhibitor levels are closely paralleled by urease content and as urease content is easier to determine, it is commonly used as an indicator of anti-nutritional factor destruction and thus to predict processing adequacy, especially under-processing. . The urease index is useful in determining whether soybean meal has been heat treated sufficiently to reduce anti-nutritional factors, but is not very useful for determining if soybean meal has been over processed. Urease values, measured by pH rise in an ammonia solution, are about 2.0 for raw soybeans. The feed industry wants urease values of 0.05 to 0.2 pH rise for properly processed soybean meal.

The application of the urease test is shown in Table 6, from work by Anderson-Haferman et al in 1992. As the processing time of raw soybeans was increased from 0-18 minutes, the weight gain of chicks increased and the pH change demonstrated that the urease had been destroyed.

Table 6. Effect of autoclaving raw soybeans on chick growth and urease index

Autoclave time (minutes)	Chick growth (g/chick)	Urease index (pH change)
0	98	2.2
3	113	2.2
6	120	2.1
9	124	1.9
12	143	0.2
15	150	0.0
18	151	0.1
Commercial SBM	158	0.2

Anderson-Haferman et al., 1992

Work by Parsons et al., 1992 has shown the effect of over-processing soybean meal. When soybeans or soybean meal are exposed to excessive heat treating, or over-processing, the negative effects that reduce the concentration and the digestibility of amino acids occur for lysine and cystine, but not for methionine or threonine (Table 6). Most of the other amino acids are also not affected by excessive heat treatment or over-processing. Thus the reduction in protein quality of soybean meal as the result of over-processing is due primarily to the combination of the destruction of lysine and cystine and the reduced digestibility of the lysine and cystine that is not destroyed.

Table 6. Effect of over-processing on amino acid concentrations and digestibility of commercial soybean meal

	Digestibility coefficient (%)			
Autoclave time (mins)	Lysine	Methionine	Cystine	Threonine
0	97	82	86	84
20	78	69	86	86
40	69	62	83	80
	Analytical concentration (%)			
Autoclave time (mins)	Lysine	Methionine	Cystine	Threonine
0	3.27	0.70	0.71	1.89
20	2.95	0.66	0.71	1.92
40	2.76	0.63	0.71	1.87

Parsons et al., 1992

Over-processing can be determined by measuring protein solubility in a potassium hydroxide (KOH) solution. It is suggested that the solubility index should be 80 to 85% in commercial soybean meal.

The protein dispersibility index (PDI) is another method for distinguishing the quality of soybean meal for feed use. The PDI measures the amount of soybean meal protein dispersed in water after blending a sample with water in a high speed blender. Work by Batel et al (2000) has shown that the PDI procedure demonstrates more consistent responses to heating of soybean flakes than does urease or KOH protein solubility.

Soybean meal with a PDI between 45 and 50% and urease of 0.3 pH unit change or below may indicate that the sample is definitely high quality because it has been adequately heat processed but not over-processed.

Table 7 shows the effect of autoclaving raw soybean flakes on chick growth, with the test results of KOH solubility, urease index and PDI value. These data show that 18 minutes of autoclaving raw soybeans were required to maximise the growth of chicks. During this time there was very little change in urease index or KOH solubility values. On the other hand, the PDI decreased as autoclaving time increased, suggesting that PDI may be more sensitive than urease index or KOH solubility for determining the optimum amount of heat processing of soybean meal.

Table 7. Effect of autoclaving raw soy flakes on chick growth and chemical assay values

Autoclaving time (min)	Chick weight gain (g)	KOH protein solubility (%)	pH increase	PDI (%)
0	178[c]	97	2.4	76
6	180[c]	93	2.2	63
12	189[b]	93	2.1	63
18	204[a]	94	1.8	47
24	207[a]	81	0.2	30
30	205[a]	81	0.3	32
36	210[a]	78	0.1	24
Commercial SBM	-	78	0.1	-

Engram, Douglas, Shirley and Parsons, unpublished. Dudley-Cash (1999)
Means with common superscripts are not significantly different ($P<0.05$)

The KOH solubility, urease index and PDI value provide an excellent means to predict adequacy of heat treatment during processing, but are not practical for use in feed mills. Most nutritionists routinely monitor moisture and protein in soybean meal but would rarely change their database based on compositional changes.

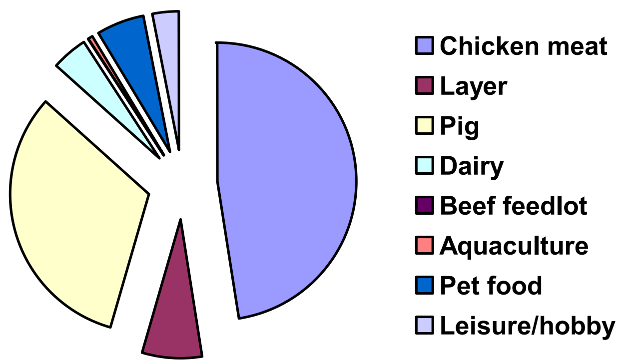
Full Fat Soybean meal (FFSB)
Although full fat soybean meal as an animal feed ingredient may appear related to soybean meal, in practice it is a different ingredient with different nutritional composition and processing conditions compared with soybean meal.

There are a number of processes used by the industry to produce FFSB. Some of these processes are dry (eg toasting) and some are wet (eg wet extrusion). Their main objective is to destroy those anti-nutritional factors present in the grain that are thermolabile. The most important consideration when choosing to buy from a supplier of FFSB is that the heat treatment applied, whichever process, is done correctly. When the conditions of the treatment are too mild (under-processing), part of the protease inhibitors are not destroyed and therefore protein digestibility and nutrient utilisation will be affected negatively. If the treatment is excessive (over-processing), the anti-nutritional factors will be destroyed but also the quality of the protein will be affected. The heat from processing has another benefit in that it also ruptures the oil cells inside the seed, making it more easily digested by monogastrics.

Full fat soybean meal is an excellent source of energy and protein, with special value in diets for young animals when a high nutrient concentration is required. As for other feed ingredients, the level of inclusion of full fat soybean meal in diets depends on its relative cost to other energy (mainly animal fat) and protein (fish meal and soybean meal) sources.

Soybean meal utilisation by species
Approximately 85% of the total soybean meal usage in Australia is fed to pigs and poultry (Table 6). The chicken meat industry is the major user, consuming about 50% of all soybean meal used by the livestock industries. The pig industry is the next biggest user, at about 35%.

Fig 2. Australian Soybean Meal Usage



Source: Total Feed usage supplied by The Stockfeed Manufactures Association. Soybean usage as a % of diet supplied by industry representatives.

Pigs and Poultry
Soybean meal dominates the market for protein supplements for pigs and poultry. There are a number of reasons for this, including its consistency in nutrient content, its ready availability year round, and its high content of crude protein. Because pig and poultry producers desire high-energy diets, soybean meal is of superior value because no common plant protein feedstuff exceeds soybean meal in digestible energy content. Soybean meal also matches or exceeds all other common plant proteins in both total and digestible amino acid content.

Soybean meal is typically included in pig and poultry diets with no limitation on the quantity used. When properly processed to denature the trypsin inhibitors, there are no antinutritive factors to consider when formulating diets.

Aquafeed
Fishmeal and meat meal form the major component of the aquafeed composition, although there is increasing interest in the use of vegetable sources. Australian aquafeed production is estimated to be 55,000 tonnes, in contrast to the pig and poultry industries that consume in excess of 4.3 million tonnes of feed. As a result, the industry consumes less than 2% of all soybean meal used by the livestock industries.

Dairy and beef
In dairy and beef cattle diets, soybean meal competes with urea and higher fibre oilseed meals. Where a high quality protein source is essential, the economics of supply and demand usually favour those crude protein sources not normally used in pig and poultry diets. Soybean meal, does however, have a role in calf nutrition and may be used in dairy calf milk replacers due to its palatability and digestibility.

Petfood
Quantities of soybean meal are also used in the formulation of pet foods and is the most common plant protein source used.

Improving the nutritive value of soybean meal
Phosphorus
Soybean meal contains one of the highest levels of phosphorus (P) of all plant proteins, yet much of it is present in a complex with phytic acid, rendering the phosphorus in a poorly digested form for monogastric animals. Due to the large amounts of undigested dietary P, a substantial amount is excreted in the manure. This poses an environmental concern, especially in areas of the world where land and water resources are scarce and livestock population density is high. The addition of microbial phytase to diets increases the digestibility of phosphorus and decreases phosphorus excretion. The addition of phytase supplements may become more commonplace in Australia as the pressure to reduce nutrients in effluent increases. Any genetic improvement to soybeans to increase phosphorus availability could decrease diet cost and phosphorus excretion and increase dietary energy concentration. This would be beneficial to the pig and poultry industries.

Oligosaccharides
Carbohydrate components in soybean meal are hulls, sugars and non-starch polysaccharides, all of which are poorly digested in monogastric animals. The dilution effect of these undigested carbohydrates reduces nutrient density and reduces the amount of energy the chick and pig can derive from the meal. Soybean hulls can be removed prior to oil extraction resulting in a meal that is higher in both protein and energy. The oligosaccharide sugars are more difficult to remove requiring an additional step with water and alcohol. The resulting product, called soy concentrate, is not cost effective for animal feed.

In poultry feed, the use of supplemental alpha-galactosidase enzyme has been investigated as a potential means to increase ME content by releasing energy from these indigestible sugars, but so far has shown inconsistent benefits (Swick 2001).

Any breeding program that improves the digestibility of the oligosaccharides offers tremendous potential in improving the available energy in soybean meal for monogastric animals.

Conclusion
Soybean meal is universally accepted as the most important protein ingredient in animal diets.

Full fat soybean meal is also a valuable raw material in diets used in the pig and poultry industries. It is not only is it a useful source of protein and essential amino acids, but also makes a significant contribution to the dietary energy requirement.

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